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DECLARATION

I declare that this dissertation entitle "Analysis of Voltage Stability Problems in Power System" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Noor Ropidah binti Bujal .....

Date : .....

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APPROVAL

I hereby declare that I have read this dissertation and in my opinion this dissertation is sufficient in terms of scope and quality as a partial fulfillment of Master of Electrical Engineering (Industrial Power).

Signature :…….....

Supervisor Name :Marizan bin Sulaiman…….....

Date :…….....

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DEDICATION

To my beloved daughter

Zara Sakina Binti Mohammad Zuhaidi

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ABSTRACT

Voltage stability analysis is important in power system in order to maintain the power system equilibrium. This research focuses on the voltage stability analysis of the power system feeders at distribution and transmission systems. The voltage stability analysis is carried out on the basis of single feeder comprising of two-bus system using ABCD line parameters. The feeder's voltage in distribution and transmission system has been monitored at lagging and leading load conditions for various power factors. Hence, the active power-voltage (P-V) curve and reactive power-voltage (Q-V) are used as tools to monitor the voltage stability at feeders. The plotting methods for PV and QV curves have been improved by using MATLAB applications software. The voltage critical, voltage regulation, voltage gap and line current are monitored at each load power factor. The results of P-V and Q-V curves show very high accuracy for both lagging and leading load condition and these results agree with previous research outputs. The voltage stability analysis incorporates the Graphical User Interface (GUI) for user friendly suitable for teaching, learning and training application. The GUI is implemented using MATLAB GUI and this software package is targeted for engineering students and practicing engineers.

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ABSTRAK

Analisis kestabilan voltan adalah sangat penting dalam sistem kuasa untuk memastikan sistem kekal berada dalam keseimbangan. Fokus kajian ini adalah dalam menganalisa kestabilan voltan di setiap penyuap voltan dalam sistem kuasa khususnya dalam sistem pengagihan dan sistem penghantaran kuasa. Analisis kestabilan voltan ini dijalankan ke atas sistem dua-bas dengan menggunakan parameter talian ABCD. Voltan di setiap penyuap voltan dalam sistem pengagihan dan penghantaran kuasa dipantau bagi beban yang mengekor dan beban yang mendahulu untuk pelbagai faktor kuasa. Oleh itu, graf lengkung kuasa sebenar-voltan (P-V) and graf lengkung kuasa reaktif – voltan (Q-V) digunakan sebagai alat untuk memantau kestabilan voltan di penyuap voltan. Kaedah memplot graf lengkung P-V dan Q-V juga ditambah baik dengan menggunakan perisian aplikasi MATLAB. Jumlah voltan kritikal, peratus pengaturan voltan, jurang voltan dan arus talian dipantau pada setiap faktor kuasa beban. Graf lengkung P-V dan Q-V yang diperolehi menunjukkan ketepatan yang tinggi untuk kedua-dua keadaan beban mengekor dan mendahului dan keputusan ini bertepatan dengan hasil penyelidikan sebelumnya. Analisa kestabilan voltan ini juga digabungkan dengan satu antaramuka grafik pengguna untuk tujuan pengajaran, pembelajaran serta latihan. Antaramuka pengguna juga dibangunkan menggunakan perisian MATLAB GUI dan pakej perisian ini disasarkan untuk pelajar-pelajar kejuruteraan dan jurutera–jurutera pelatih.

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ACKNOWLEDGMENTS

Alhamdulillah, all praises to Allah for everything. First and foremost, I would like to express my sincere appreciation to my supervisor, Engr. Prof. Dr. Marizan bin Sulaiman for his supervision and endless support. His guidance and advices helped me in completing this dissertation. I could not have imagined having a better supervisor for my study.

Special thanks to Universiti Teknikal Malaysia Melaka (UTeM) for giving me the opportunity to pursue Master of Electrical Engineering (Industrial Power) here. It just like a dream comes true.

I also want to express my warm thanks to my colleagues who supported me in this dissertation for all their help, support, interest and valuable hints. Sincere thanks to all my fellow friends in UTeM for the help, friendship and sweet memories.

Last but not least, my deepest gratitude goes to my beloved husband Mohammad Zuhaidi Mohd Noor and my daughter Zara Sakina Mohammad Zuhaidi for their endless love, prayers, supports, sacrifices and encouragement. Thank you very much once again to every single person who directly or indirectly contributed to this research.

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LIST OF ABBREVIATIONS

AC	-	Alternating current
C	-	Capacitance
FACT	-	Flexible AC transmission
GUI	-	Graphical user interface
IEEE	-	Institute of Electrical and Electronics Engineers
KCL	-	Kirchhoff Current law
kV	-	Kilo volt
LTC	-	Load tap changing
MATLAB	-	Math lab works
MVA	-	Mega Volt ampere
MW	-	Mega watt
P-V	-	Power to voltage
Q-V	-	Reactive power to voltage
R	-	Resistance
STATCOM	-	Static synchronous compensators
SVC	-	Static VAR compensators
TNB	-	Tenaga Nasional Berhad
VAR	-	Volt ampere reactive

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LIST OF SYMBOLS

ω	-	Angular frequency
°	-	Degree
π	-	Pi
E_{Rcr}	-	Critical voltage
Ic	-	Capacitor Current
I_R	-	Receiving-end current
I_S	-	Sending-end current
L	-	Inductance
l	-	Line length
P	-	Real power
p.f	-	Power Factor,
P_R	-	Receiving-end real/ active power
P_R	-	Receiving-end active power
P_{Rmax}	-	Maximum receiving-end active power
Q	-	Reactive power
Q_R	-	Receiving-end reactive power
Q_{Rmax}	-	Maximum receiving-end reactive power
r	-	Per-phase resistance
S	-	Apparent Power/ Complex Power
V_{cr}	-	Voltage Critical

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V_{gap}	-	Voltage gap
V_R	-	Receiving-end voltage
V_{rated}	-	Rated Voltage
V_{Rcr}	-	Critical Receiving End Voltage
V_{reg}	-	Voltage regulation
V_{RFL}	-	Full-load receiving end
V_{RNL}	-	No-load receiving end
V_S	-	Sending End Voltage, and
Y	-	Admittance
Z	-	Series impedance
δ’	-	Delta prime
δ'_{cr}	-	Prime critical angle
δ_{cr}	-	Delta Critical
η	-	Efficiency
θ	-	Theta
ϕ	-	Phi (Power factor angle)
ϕ'	-	Phi Prime

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LIST OF PUBLICATIONS

[1] Analysis of Voltage Stability Problems in Power System. Accepted for presentation in International Conference "Engineering- *Technology & Technopreneurship"* on 27-29 August 2014.

[2] A Graphical User Interface (GUI) for Voltage Stability Analysis. Accepted for presentation in National Conference *"Conference in Education-Technical Vocational Education and Training"* on 26 August 2014.

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CHAPTER 1

INTRODUCTION

1.1 Background

Power system stability is an ability of electric power system to regain a state of operating equilibrium after being subjected to a disturbance (Dorf, 2007). There are three classes of power system stability, namely rotor angle stability, frequency stability and voltage stability (Dorf, 2007). Voltage stability is in respect of the ability of a power system to maintain steady voltage at all busses in the system under normal condition and after being subjected to a disturbance (Kundur, 2004). However, voltage instability may occur either when voltage fall or rises at some busses. Therefore, the voltage stability analysis should be implemented to monitor the voltage stability at voltage feeder and improves the power system stability.

The quantity of power transmitted is based on power factor and ABCD line parameters. The load condition at transmission feeder will affect the transmission line performance in terms of voltage critical, voltage drop, voltage regulation and transmission line current. P-V curve and Q-V curve are widely used to monitor the voltage stability of distribution and transmission feeder (Khan, 2007). Therefore, in this study, P-V and Q-V curve for various power factors are used as a tool for analyzing voltage stability.

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1.2 Motivation of Research

The research has been done with the fact that voltage at each feeder system plays a significant role in power system. Therefore the voltage should be monitored to avoid the power system failure. This research focuses on voltage stability by monitoring real power demand (P), reactive power (Q) and receiving end voltage (V_R) at the feeder of the transmission system and distribution system compared to previous researches that study one of the curves and separately.

The P-V curve and Q-V curve are simple methods to use as tools to monitor the voltage and power because it can represent the whole system performance with single graph. Besides, voltage regulation and voltage gap for different lagging and leading load conditions are also associated with the voltage stability. The P-V and Q-V plotting method need to be improved with more points or interval to ensure the accuracy of the analysis.

1.3 Problem Statement

In power system, a bulk of power is transmitted to load through a transmission and distribution line. There are loads that operate at either lagging or leading power factor. Each type of load will give different effects to the transmission and distribution feeder and may cause voltage stability problems.

The load conditions also affect the performance of both system feeder in terms of voltage regulation, voltage gap and line current. Therefore, the voltage at a different feeder of transmission and distribution systems should be calculated and monitored by using P-V and Q-V curve. The curves show the variation of both power demands (P and Q) with respect to the terminal voltage of the receiving-end feeders for loads operating at either lagging or leading condition of power factors. However, previous curves plotting need a complex calculation for each load conditions. The curves also were plotted using a few

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points which not ensure the accuracy of results analysis. Besides, only P-V curves mostly used in voltage stability monitoring. The P-V and Q-V curves tracing method also need to be improved due to the complexity of calculation involved in analysis.

1.4 Research Objective

The objectives of this research are:

i. The Graphical User Interface (GUI) based software using MATLAB that has an ability to analyze Voltage Stability in Short and Medium-length transmission lines.

ii. To improve plotting method for P-V and Q-V curve for short and medium-length transmission lines by using more points based on critical angle for analysis's accuracy and using programming incorporate with GUI and display the curves based on any power factor that enter by user.

iii. To determine the voltage regulation within the acceptable region of short-length and medium-length transmission line, operating voltage, critical voltage, voltage gap and line current for different operation load conditions.

1.5 Contribution of Research

The contributions of this research include:

i. Improve tracing method for P-V and Q-V curves for short-length and medium-length transmission lines by using more points based on critical angle for analysis's accuracy and using programming incorporate with GUI and display the curves based on any power factor that enter by user. All the curve and data can be saved and retrieve at any time.

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ii. Calculations of voltage regulation, line current and voltage gap for lagging and leading load power factors for both P-V and Q-V curves to show the positive Q absorption for lagging and negative Q generation for leading.

iii. The GUI based P-V and Q-V curves can be used for teaching, learning and training package.

1.6 Scope of Research

The scope of this research covers the followings:

i. The voltage stability analysis for short-length and medium-length transmission line only.

ii. The P-V curve and Q-V curve are plotted to monitor voltage at the transmission line feeder.

iii. The voltage regulation, line current and voltage gap are calculated to monitor the lines performance.

1.7 Organization of Dissertation

This dissertation is divided into five chapters. Chapter 1 introduces about the research background, research motivation, problem statement, research objectives and scope of research. Chapter 2 will focus on the related literature review and theoretical background of the research. Basic theory of both short-length and medium-length transmission line are discussed in this chapter.

Chapter 3 concentrates on the system design and development process. Algorithms that are used and all calculations are presented in this chapter. The development of the software for designing the analysis system and GUI development will also be discussed. Chapter 4 is a discussion of the results that are obtained from the simulation carried out.

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The simulation results then were analyzed to identify the acceptable power factor for the short-length and medium-length transmission line for different lagging and leading power factors of load conditions. The discussion also includes the importance of P-V and Q-V curves at each feeder and the effect of lagging and leading load power factors variation at line feeder. Chapter 5 is a conclusion that summarizes all the research work that has been done. The suggestion for further research will be also highlighted at the end of the chapter.

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CHAPTER 2

LITERITURE REVIEW AND THEORETICAL BACKGROUND

2.1 Introduction

This chapter will discuss mainly on the literature review and theoretical background of voltage stability analysis, active power to voltage (P-V) and reactive power to voltage (Q-V) curve, voltage regulation, line efficiency and voltage gap.

2.2 Literature Review

According to Zang et al. (2010), the techniques to perform voltage stability analysis fall into two categories which are static and dynamic. Static Voltage stability analysis has been chosen to recognize the weak area in terms of reactive power insufficiency and unforeseen event in the system. From that, the voltage stability margin for different power transfers can be obtained within the system. This paper also agrees that power-voltage curves and reactive–voltage curve are commonly used to determine system weakness, weak point, margin of instability and voltage collapse. A tool was built up using programming language Python for shortage screening and P-V analysis. Furthermore, this literature focuses on the determination of the voltage instability region in order to recognize voltage collapse area through P-V and Q-V curve by using Phyton tools.

Vargas et al. (2009) state that P-V curves normally used to assess the operating condition of the power system. P-V curves are graphic indicator to show how the voltage on the load bus varies according to real power, P flows to Load."Nose" of the curve shows the maximum power transfer and also known as the critical point. The curve is a plot based

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